Truncation in Myocardial Perfusion SPECT Imaging

Brian Wosnitzer *, Marvin Friedman, Gordon DePuey

Division of Nuclear Medicine, St Luke's Roosevelt Hospital Center, New York, NY, USA

bwosnitzer@chpnet.org

Abstract

Myocardial perfusion single photon emission computed tomography (SPECT) imaging (MPI) is commonly used to evaluate patients for myocardial ischemia. One confounding factor during scan interpretation is imaging artifacts. Physicians must be aware of the various imaging artifacts that may occur to avoid false positive results. Truncation of the heart during nuclear imaging has been previously described but has not been emphasized as much as other imaging artifacts. Truncation leads to artifacts in the reconstructed tomographic images, which may be misinterpreted as perfusion defects. We recently reported a case where truncation of the myocardium occurred in the planar stress and rest acquisition datasets. Currently, we report a case of truncation of the heart which was not present in the original planar stress acquisition dataset, but rather was introduced by shifting of the image sequences during the automated joining of the two separate detector datasets, an integral part of multidetector SPECT reconstruction.

Keywords

Myocardial; Perfusion; SPECT; Truncation; Artifacts

Case Report

A 38 year-old male was referred for a single day gated rest/stress Tc-99m sestamibi MPI study for the evaluation of dyspnea and atypical chest pain. His medical history included HIV, hypertension, dyslipidemia, tobacco use, and cocaine use. The patient's height, weight, and chest circumference were 5'4", 275 pounds, and 52 inches respectively. A standard weight-based low-dose rest (11.9 mCi) / high-dose stress (48.2 mCi) Tc-99m sestamibi protocol was used. Standard exercise stress with Bruce protocol was performed, and the patient reached 90% of maximal predicted heart rate. The patient experienced no chest pain and there were no ST segment changes during exercise. All images were acquired on a GE Millennium MG™ dual detector camera in the "cardiac" or 90-degree mode using a 90-degree gantry rotation, "body-centered" circular orbit, and a low energy, high resolution collimator. Specifically, neither a cardio-centric or body-contoured orbit was used. Images were processed with ordered subset expectation maximization (OSEM) using Myovation™ software on a GE Xeleris™ workstation.

Raw Images (A-E)   Processed Images (F-J)

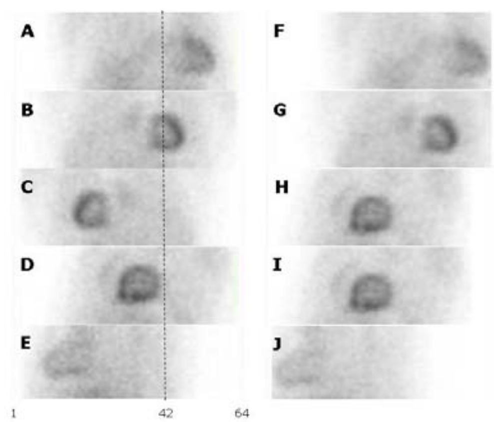

FIGURE 1 SEQUENCE OF ACQUIRED INITIAL STRESS PROJECTION IMAGES FROM DETECTOR I, A=RIGHT ANTERIOR OBLIQUE VIEW (RAO), B=ANTERIOR (ANT) VIEW, C=LAST LEFT ANTERIOR OBLIQUE (LAO) VIEW AND FROM DETECTOR II, D=FIRST LAO VIEW, E= LEFT LATERAL VIEW (LLAT)

Review of the post-processing "rotating" planar images in endless loop cinematic format demonstrated truncation of the tip of the apex of the heart in the stress extreme RAO and left lateral images (Figures 1F-1J), but not in the rest images. The reconstructed stress tomographic images and stress polar plot (Figure 2, Figure 3) demonstrated increased counts at the apex resulting from inconsistent projection data arising from the truncation. The relatively decreased counts in the basal anterior wall, inferior wall, lateral wall, and septum is due to the normalization of the stress

tomographic images to the “hot” apex[1]. Together, these artifacts rendered this study uninterruptible.

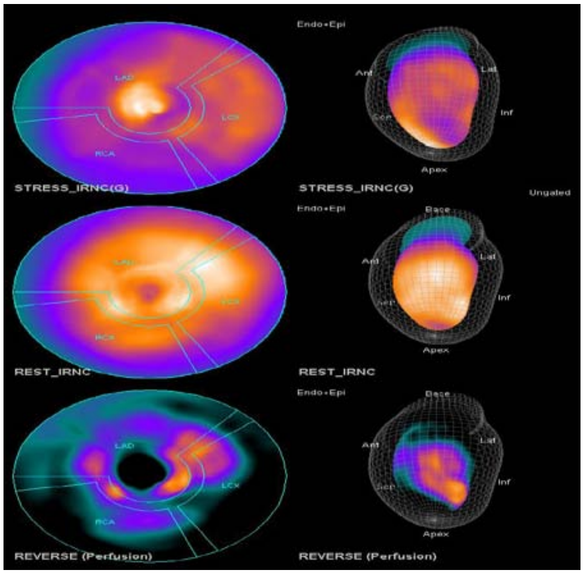

FIGURE 3 STRESS, REST, AND REVERSIBILITY POLAR PLOTS DEMONSTRATE APPARENT REVERSIBLE PERFUSION DEFECTS INVOLVING THE BASAL ANTERIOR WALL, INFERIOR WALL, LATERAL WALL, AND SEPTUM. THE STRESS POLAR PLOT AND

An exercise stress-only study was repeated three days later. The repeat study used the same exercise stress protocol with a stress dose of 26.2 mCi of Tc-99m sestamibi. The patient reached 91% of maximal predicted heart rate and again, the patient experienced no chest pain and there were no ST segment changes during exercise. The post-stress imaging technique was identical to the initial stress acquisition technique, with the exception that the patient was asked to move slightly to his right on the pallet. Review of the post-processing repeat stress “rotating” planar images in endless loop cinematic format demonstrated no truncation of the tip of the apex of the heart (Figures 4F-J). The repeat stress tomographic images and stress polar plot demonstrated homogeneous tracer distribution throughout the entire left ventricular myocardium, indicating no scan evidence of exercise-induced ischemia (Figure 5 and Figure 6).

Raw Images (A-E) Processed Images (F-J)

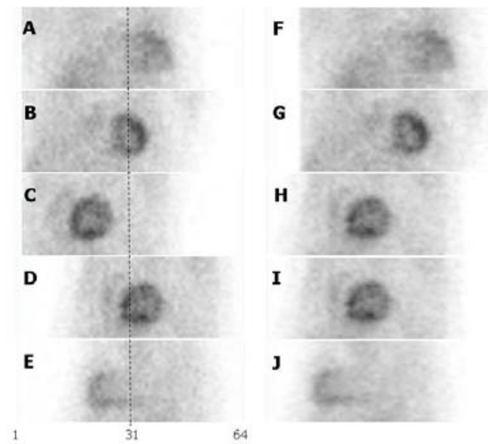

FIGURE 4 SEQUENCE OF ACQUIRED REPEAT STRESS PROJECTION IMAGES FROM DETECTOR I, A=RIGHT ANTERIOR OBLIQUE VIEW (RAO), B=ANTERIOR (ANT) VIEW, C=LAST LEFT ANTERIOR OBLIQUE (LAO) VIEW AND FROM DETECTOR II, D=FIRST LAO VIEW, E= LEFT LATERAL VIEW (LLAT)

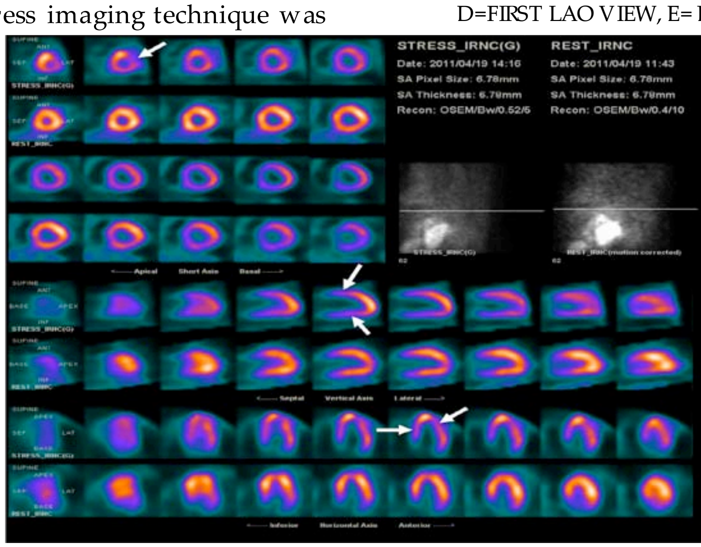

FIGURE 2 RECONSTRUCTED STRESS TOMOGRAPHIC IMAGES DEMONSTRATE INCREASED COUNTS AT THE APEX DUE TO INCONSISTENT PROJECTION DATA. THE APPARENT DECREASE IN COUNTS IN THE BASAL ANTERIOR WALL, INFERIOR WALL, LATERAL WALL, AND SEPTUM IS A RESULT OF NORMALIZATION OF THE STRESS IMAGES TO THE “HOT” APEX. ABSENCE OF ARTIFACTS IN THE RECONSTRUCTED REST TOMOGRAPHIC IMAGES SUGGESTS REVERSIBLE PERFUSION DEFECTS WHICH CAN BE MISINTERPRETED AS ISCHEMIA

Discussion

Although the truncation artifact has previously been described in the literature, it has not been emphasized to the same extent as other cardiac artifacts [2-8]. We previously reported a case truncation of the heart, which occurred on both stress and rest studies[2]. If the extent of truncation of the heart is identical on both stress and rest studies, the apparent perfusion defects on reconstructed tomographic images may be falsely interpreted as fixed defects, thus indicating myocardial scarring [1, 2]. Alternatively, if truncation occurs only at stress or is more extensive in the stress study, the apparent perfusion defects may appear worse in the stress images, suggesting reversible perfusion defects, and thus ischemia [1, 2]. Currently, we report a case of truncation of the heart which occurred only in the stress study. The truncation was not present in the original stress acquisition dataset, but rather was introduced by the shifting of the image sequences during the automated joining of the two separate detector datasets, an integral part of multidetector SPECT reconstruction.

SPECT reconstruction algorithms for dual 90-degree detector acquisition of myocardial perfusion scans usually utilize as input a composite image set that emulates an acquisition with a single detector rotating through 180 degrees. This composite image set is created by joining the image sequence from the second detector to the end of the image sequence from the first detector. However, the images within each sequence must first be shifted to compensate for the center-of-rotation for the applicable detector (usually less than 2 mm), and separately to correct for the difference in the locations (~ several cm) of the heart in the image matrices of the two detectors at the viewing angle at which the joining occurs (typically an LAO view). Without this correction the composite image set would appear to demonstrate lateral patient motion in the middle of the angular sequence, and reconstructed images would consequently contain image artifacts.

The original planar stress acquisition dataset in this case did not demonstrate cardiac truncation (Figures 1A-1E). Rather, truncation was introduced by the image shifting during creation of the composite image set (Figures 1F-1J). For circular camera orbits, the (matrix) position of the heart in successive MPI projection images varies sinusoidally, with an amplitude that is determined by the distance between the gantry axis of rotation and the center of the heart[1, 4]. In this case, the cause of the truncation in the joined dataset was the large variation of position in the image matrix of the myocardium in each detector's angular dataset. In the original stress acquisition of the first detector, the center of the myocardium started at pixel 51 in the RAO view (Figure 1A), moved through pixel 42 for the anterior view (Figure 1B), and to pixel 24 at its last angle at 45 degrees LAO (Figure 1C). Simultaneously, the center of the myocardium started at pixel 34 in the 45 degree LAO first view of the second detector (Figure 1D) and moved to pixel 13 in its LLAT view (Figure 1E). There was no apical truncation. When these datasets were joined in sequence, the center of the myocardium started at pixel 57 in the first RAO view (Figure 1F) and moved to pixel 5 in the LLAT view (Figure 1J). At these extreme pixel values, the apex of the myocardium was cut off in the initial and final angular views.

The most effective way to ensure against such processing-induced truncation is to employ a more cardio-centric orbit by either moving the imaging pallet, or asking the patient to move on the pallet to his or her right so as to reduce the distance between the axis of rotation and the patient's heart (Figure 7A,B). Prior to SPECT imaging, this distance would be most readily appreciated in a persistence mode anterior image. In the repeat stress acquisition, movement of the patient slightly to his right on the pallet eliminated the apical truncation in the extreme angular views. In the repeat stress acquisition, the center of the myocardium started at pixel 37 of the first detector in the RAO view (Figure 4A), moved through pixel 31 for the anterior view (Figure 4B), and to pixel 20 in its last angle at 45 degrees LAO (Figure 4C). Simultaneously, the center of the myocardium started at pixel 35 in the 45 degree LAO first view of the second detector (Figure 4D) and moved to pixel 24 in its LLAT view (Figure 4E). When these datasets were joined in sequence, the center of the myocardium started at pixel 45 in the first RAO view (Figure 4F) and moved to pixel 17 in the LLAT view (Figure 4J). There was no truncation of the myocardium—the variation in location of the myocardium was reduced because the heart was positioned closer to the central axis of rotation.

We recommend that before initiation of scanning, the technologist ensure that the center of the myocardium in the anterior view (first detector only) is within 5 pixels of the center of the image. In this case, the center of the myocardium fell at pixel 42 in the anterior projection of the initial stress study (Figure 1B) and in pixel 31 in the repeat stress acquisition (Figure 4B). Additionally, before initiation of scanning, the persistence scope images should be examined for frank truncation, particularly the RAO and LPO to left lateral projections, since truncation is more likely to be visualized in these views[2].

If truncation is not initially avoided, signs of truncation should be recognized as early as possible in the scan acquisition process and certainly prior to the patient leaving the facility. Signs of truncation of the heart can be identified during scan processing in the “rotating” planar images, during selection of cardiac limits, or in the sinogram (Figure 7 A, B, Figure 8A, B)[2]. In addition, truncation can be recognized during image interpretation particularly in the “rotating” planar projection images[2]. Although in this case a repeat study on a separate day with the patient shifted slightly to his right on the pallet resolved the truncation issue, such repeat testing increases the time expenditure of the physician, technologist, and patient as well as cost for the facility and radiation dose to the patient[2].

Conclusion

In summary, we re-emphasize that recognizing and understanding the truncation artifact is necessary for both technologists and interpreting physicians in order to ensure proper scan acquisition and accurate interpretation of myocardial perfusion scans. We stress that the persistence scope images should be examined before the myocardial perfusion scan so that either patient or table position can be adjusted to optimize the distance between the axis of rotation and the center of the heart and thus prevent truncation. Lastly, “rotating” planar images, tomograms, and sinograms should be inspected for signs of truncation during image processing and interpretation. Such measures will minimize the incidence of truncation and prevent false positive scan interpretation which may lead to unnecessary procedures such as cardiac catheterization.

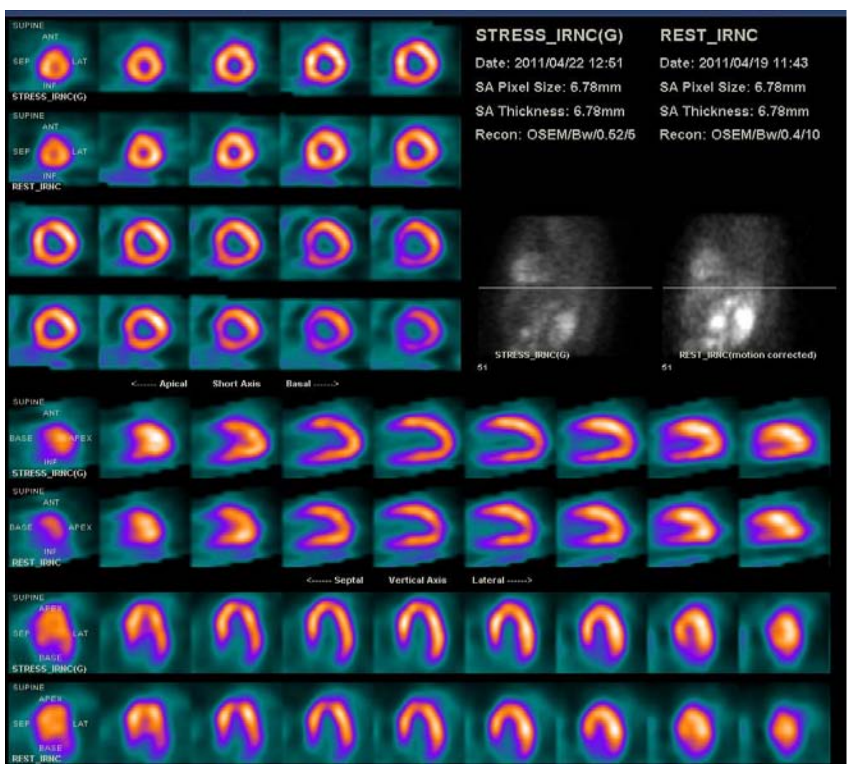

FIGURE 5 RECONSTRUCTED TOMOGRAPHIC IMAGES FROM REPEAT STRESS SCAN AND INITIAL REST SCAN DEMONSTRATE NO EVIDENCE OF TRUNCATION OF THE APEX. HOMOGENEOUS TRACER DISTRIBUTION THROUGHOUT THE ENTIRE LEFT VENTRICULAR MYOCARDIUM INDICATES NO SCAN EVIDENCE OF EXERCISE INDUCED MYOCARDIAL ISCHEMIA

After joining of the two detector datasets, F=RAO view, G=ANT view, H and I=LAO views, J= LLAT view. (For comparison, and to improve the statistics for visualization, the original stress raw dataset was converted from an 8-interval gated study to a non-gated dataset by summation of the 8 interval images for each projection.) Truncation is not demonstrated in the raw projection sequence A-E, but truncation is demonstrated in frames F (RAO) and J (LLAT) of the post-processing sequence F-J. The heart is centered at pixel 42 in the anterior view of the raw projection sequence.

After joining of the two detector datasets, F=RAO view, G=ANT view, H and I=LAO views, J= LLAT view. (For comparison, and to improve the statistics for visualization, the original stress raw dataset was converted from an 8-interval gated study to an ungated dataset by summation of the 8 interval images for each projection.) Truncation is not seen in either the raw projection sequence A-E, or in the post-processing sequence F-J. The heart is centered at pixel 31 in the anterior view of the raw projection sequence.

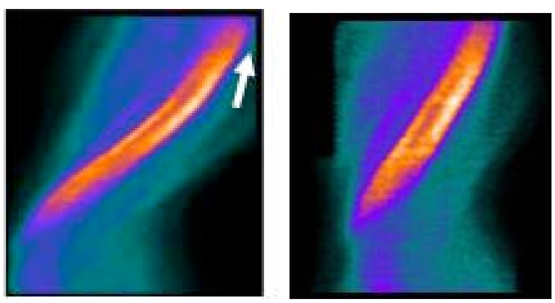

FIGURE 7 SINOGRAM FROM INITIAL STRESS (A) DEMONSTRATES TRUNCATION (WHITE ARROW). SINOGRAM FROM REPEAT STRESS (B) IS MORE VERTICALLY ORIENTED REPRESENTING A MORE "CARDIO-CENTRIC" ORBIT RATHER THAN A "BODY-CENTRIC" ORBIT.

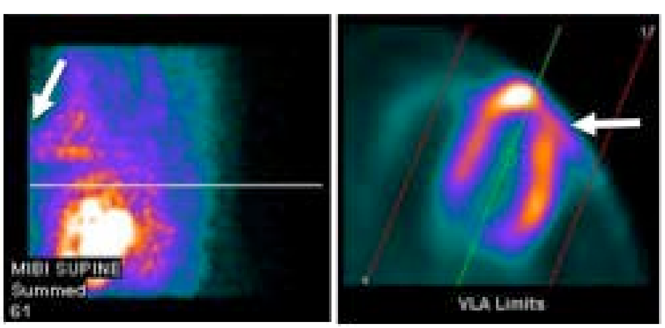

FIGURE 8 TRUNCATION IS ALSO VISUALIZED DURING IMAGE PROCESSING IN THE "ROTATING" PLANAR PROJECTION IMAGES (A) AND IN THE RECONSTRUCTED TRANSAXIAL TOMOGRAM (USED TO SELECT THE VENTRICULAR LONG AXIS (B)

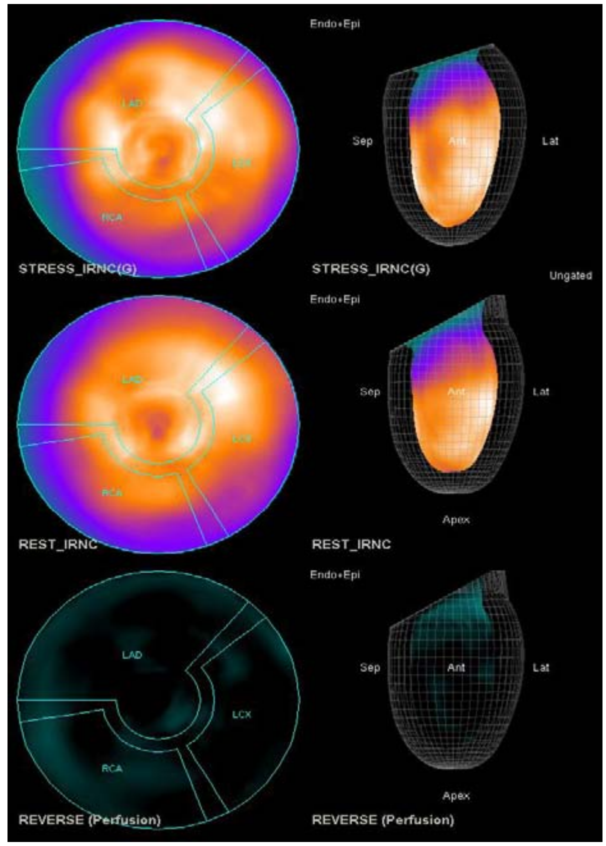

FIGURE 6 REPEAT STRESS, INITIAL REST, AND REVERSIBILITY POLAR PLOTS AND SURFACE-RENDERED RECONSTRUCTION (TOP) DEMONSTRATE NO APPARENT PERFUSION DEFECTS

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